Comparative Nutrient Export And Economic Benefits of Conventional And Better Site Design Techniques

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Better site design describes a fundamentally different approach to the design of residential and commercial development projects. It seeks to accomplish three goals at every development site: to reduce the amount of impervious cover, to increase the amount of natural land set aside for conservation, and to use pervious areas for more effective stormwater treatment.

When designing new residential developments, planners have the opportunity to reduce stormwater runoff and pollutant export through better site design techniques. The better site design techniques applied to these developments are referred to here as "open space design," and present an alternative to conventional residential subdivisions. Also known as cluster development, open space design concentrates density on one portion of a site in order to conserve open space elsewhere by relaxing lot sizes, setbacks, frontages and road section and other lot geometry. Open space design also consists of:

- installing narrower streets and shorter driveways
- spreading stormwater runoff over pervious areas
- using open channels rather than curb and gutter
- clustering development to conserve forests and natural areas
- reducing the area devoted to turf
- protecting stream buffers
- enhancing the quality of septic system effluent in areas where sewage is disposed of on-site

When these techniques are applied together, the cumulative benefits of better site design can be impressive. Documenting the precise benefits is difficult, however, since few developments incorporating better site design techniques have been built, let alone monitored.

As most better site design techniques are non-structural in nature, the achievable benefits will vary depending on the unique characteristics of each development site and the actual site planning practices applied. Also, since better site design techniques are commonly applied together, it has been difficult to accurately quantify their individual nutrient removal benefits. Many local governments, consultants, and developers have expressed a strong desire for clear documentation of these presumed benefits.

To help meet this need, the Center for Watershed Protection (CWP) recently completed a study to document the comparative nutrient export and economic benefits of conventional and better site design techniques. The simple assessment methodology analyzed both the residential and commercial environment through four real-world development case studies in the Chesapeake Bay watershed. This paper presents the results of the residential component of that project, including the incorporation of open space design techniques into the redesign of two residential case studies; the resultant hydrologic, nutrient export, and economic benefits; and finally, the implications of our findings for the watershed manager.

Methodology

The basic method used in the Nutrient Loading from *Conventional and Innovative Site* Developmentproject (Caraco, et al., 1998) conducted by CWP is a redesign analysis that compares conventional and better site design at actual project sites using a simplified model.

CWP first assembled plans of previously developed sites representative of typical development scenarios across the Chesapeake Bay, including a medium-density residential development from Virginia's Piedmont, a large-lot single family residential subdivision from Maryland's Eastern Shore, a retail strip mall from Frederick County, Maryland, and a commercial office park located outside of the District of Columbia in suburban Maryland. Each site was then "redesigned" using better site design techniques.

The Simplified Urban Nutrient Output Model (SUNOM) was then used to compare each conventionally designed site to the redesign. SUNOM is a spreadsheet model that computes the hydrologic budget, infrastructure cost and nutrient export from any site, using common site planning variables. The model provides watershed practitioners with a simple tool to compare the costs and benefits of better site design. It is not meant to be used as a method for determining actual stormwater runoff and nutrient loading from a development site. To obtain accurate numbers for this, a more detailed model should be used or on-site monitoring should be conducted.

Model input includes basic site planning variables that can be directly obtained or measured from a typical development submittal to a land use authority, including total drainage area, length of sidewalks, total impervious cover, linear feet of roads, lawn cover, utilities (length and type), forest cover, size, type, and length of stormwater conveyance, riparian forest cover, size and type of stormwater practices, soil type(s), and method of wastewater treatment. Default data are provided for many parameters and many of these assumptions can be changed based on site specific information.

SUNOM is governed by the principles of a simplified water balance. In addition to annual runoff and infiltration, SUNOM computes the annual nutrient load from each development site in pounds. In brief, the surface nutrient export from each site is estimated using the Simple Method (Schueler, 1987). This export is then adjusted to reflect the mean removal capability of stormwater BMPs where present (Schueler, 1997). The subsurface component of the model utilizes annual subsurface recharge rates (based on the site's prevailing hydrologicsoil group) and monitored baseflow nutrient concentrations in the receiving water to estimate the annual subsurface nutrient export from urban areas. These values are then adjusted for the area of the site that cannot recharge (i.e., impervious cover) or are hindered from infiltrating by other conditions (e.g., compacted urban turf). The model also calculates the cost of development utilizing previously published or user-specified unit costs and predictive equations for infrastructure, stormwater management, landscaping, and septic systems.

For each case study, SUNOM was used to compare the annual hydrologic budget and annual nutrient export under five development scenarios: pre-developed conditions, conventional design without stormwater practices (uncontrolled), conventional design with stormwater practices (controlled), design incorporating better site design techniques without stormwater practices (uncontrolled), and design incorporating better site design techniques with stormwater practices (controlled). The cost of development associated with each design was also estimated.

Case Study #1: Duck Crossing, A Low Density Residential Subdivision

Duck Crossing, a large-lot residential development, is located in Wicomico County on Maryland's Eastern Shore. Prior to development, the parcel was representative of the typical terrain on Maryland's coastal plain, with very little gradient. The site contained tidal and non-tidal wetlands, natural forest, meadow, the 1 00-year floodplain, as well as three existing dwellings with on-site sewage disposal.

The large-lot subdivision of single family homes, constructed in the 1990's, (Figure 1) contains eight new residential lots, each of which are 3 to 5 acres in size with houses set far back from the street. The street is wide given the few homes that are served, ends in a large cul-de-sac, and is lined with a sidewalk. Each lot has an on-site private septic

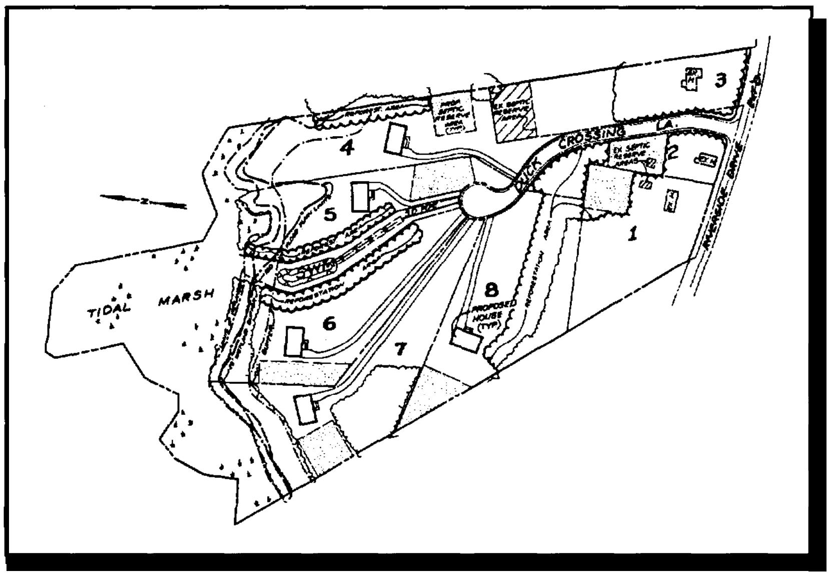

Figure 1. The conventional design of Duck Crossing, a low density residential subdivision on Maryland's Eastern Shore.

system, with a septic reserve field of about 10,000 square feet. Individual home property lines extend to the protected tidal marsh, which is the only common open space on the site. Stormwater management consists of street runoff conveyed by curb and gutter to a storm drain system that discharges to a small wet pond.

The major better site design techniques applied when redesigning this site (Figure 2) included:

- conservation of tidal and non-tidal wetlands and forested areas
- a 100-foot buffer along tidal and non-tidal wetlands
- clustering development to provide additional open space
- identification of potential development and open space areas based on location of sensitive areas, 100-year floodplain, and potential septic field areas
- distribution of stormwater treatment practices throughout the site
- use of a narrower access road; shorter, shared driveways; and wood chip paths through community open space instead of sidewalks along the road
- use of shared septic systems utilizing more advanced re-circulating sand filter technology

The open space design resulted in reduced impervious cover, reduced stormwater runoff, increased stormwater infiltration, and reduced infrastructure cost over the conventional design.

Case Study #2: Stonehill Estates, A Medium-Density Residential Subdivision

Stonehill Estates is located in Stafford County just north of Fredericksburg, Virginia. The original site was almost entirely forested in a mix of mature deciduous hardwoods, with perennial and intermittent streams, and non-tidal wetlands. An existing network of public water and sewer lines serves the site and road access to the subdivision is by two existing streets.

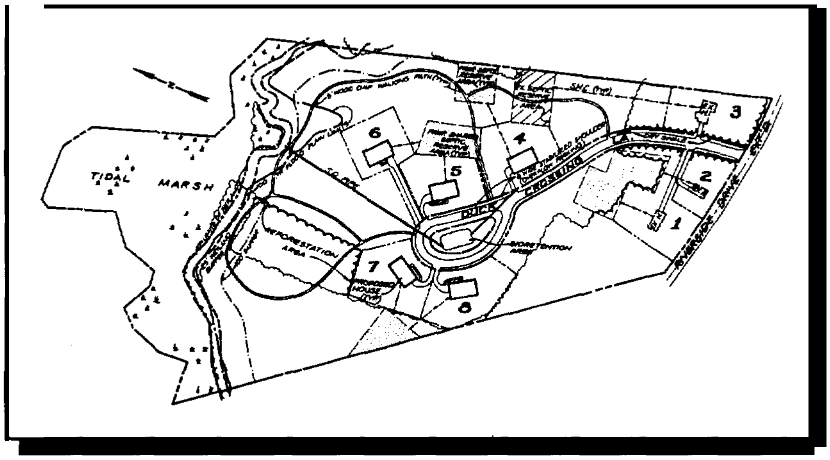

Figure 2. The open space design of Duck Crossing.

The conventional design produced a total of 108 house lots, each of which are about 9000 square feet in size (Figure 3). The subdivision is quite typical of a medium-density residential subdivision developed in the last two decades in the Mid

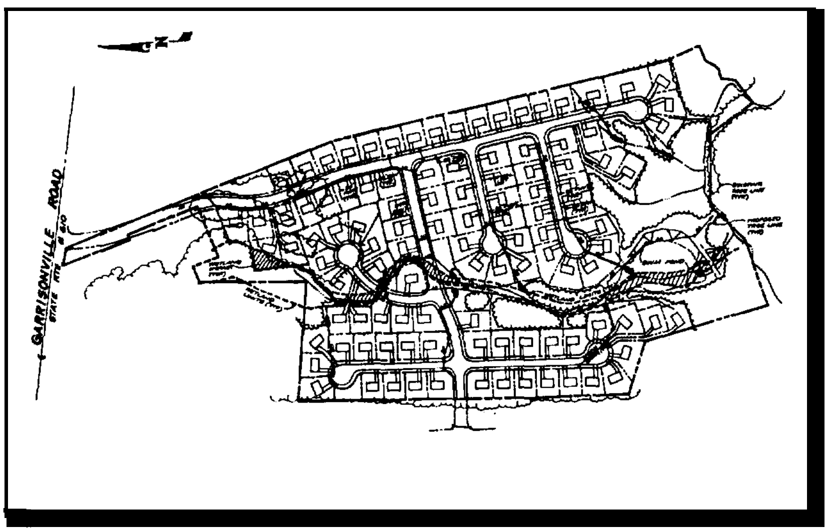

Figure 3. The conventional design of Stonehill Estates, a medium density residential subdivision in Stafford County, Virginia.

Atlantic with uniform lot sizes and shapes, and generous front setbacks. The streets were 34 and 26 feet wide, numerous cul-de-sacs were used as turnarounds, and sidewalks were generally installed on both sides of the street. With the exception of a small tot-lot, the majority of the open space is unbuildable land, such as floodplains, steep slopes, wetlands, and stormwater management areas. Street runoff is conveyed by curb and gutter to a storm drain system that discharges to the intermittent stream channel. It then travels to a dry extended detention pond, which is primarily used to control flooding, but also provides limited removal of stormwater pollutants.

The open space design also results in 108 lots, but these were slightly smaller with an average size of 6,300 square feet. The design also incorporates many techniques of open space design as advocated by Arendt (1994). The design techniques employed in the redesigned site (Figure 4) include:

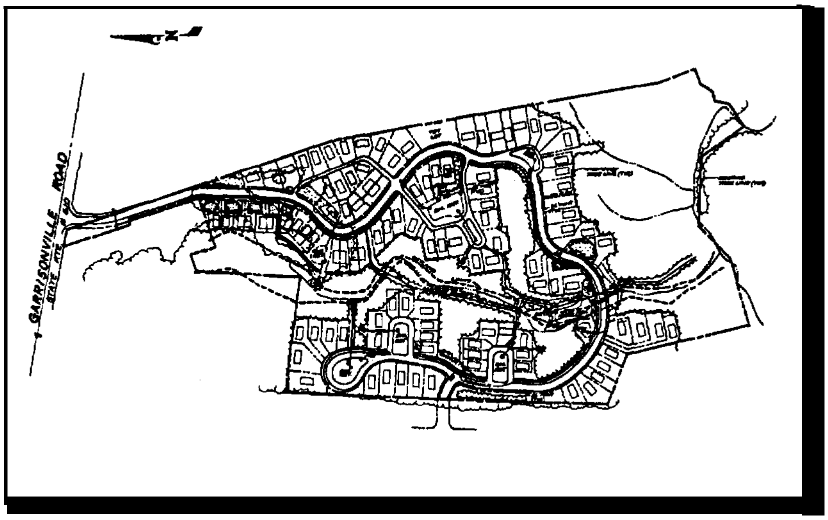

Figure 4. The open space design of Stonehill Estates.

- identify sensitive natural features, including mature forest and wetland, to be protected
- incorporate a minimum 1 00-foot buffer along all perennial and intermittent streams
- maximize the amount of community open space and preservation of natural areas
- maintain the same number of lots as the conventional design
- provide open space adjacent to as many lots as possible
- incorporate stormwater management attenuation and treatment throughout the site
- use narrower streets, loop roads, shorter driveways, and fewer sidewalks
- allow for irregular shaped lots and shared driveways
- manage stormwater in a "treatment train" with bioretention facilities that discharge to a small but more effective wet pond

The open space design resulted in reduced impervious cover, reduced stormwater runoff, increased stormwater infiltration, and reduced infrastructure cost over the medium density subdivision conventional design (Table 1).

The Benefits of Open Space Design

For both of these case studies, application of the open space design techniques resulted in reduced impervious cover, which translates directly to reduced stormwater runoff. Other "redesign" studies recently conducted in Delaware, Maryland, and Virginia have provided similar results. These combined results consistently demonstrate that better site design can reduce impervious cover by 25 to nearly 60% and stormwater runoff by 4 to over 60% for a range of subdivisions (Table 1).

Table 1. Redesign Analyses Comparing Impervious Cover and Stormwater Runoff from Conventional and Open Space Subdivisions

Residential Subdivision	Conventional Zoning for Subdivision	Impervious Cover at the Site			% Reduction in Stormwater Runoff
		Conventional Design	Open Space Design	Net Change	
Duck Crossing	3 - 5 acre lots	8%	5%	- 35%	23%
Stonehill Estates	1/3 acre lots	27%	21%	- 24%	24%
Remlik Hall [1]	5 acre lots	5.4 %	3.7%	-31%	20%
Tharpe Knoll [2]	1 acre lots	13%	7%	- 46%	4%
Chapel Run [2]	½ acre lots	29%	17%	-41%	31%
Pleasant Hill [2]	½ acre lots	26%	11%	- 58%	54%
Prairie Crossing [3]	½ - 1/3 acre lots	20%	18%	- 20%	66%
Buckingham Greene [2]	1 /8 acre lots	23%	21%	- 7%	8%
Belle-Hall [4]	High Density	35%	20%	- 43%	31%

sources: [1] Maurer, 1996; [2] DE DNREC, 1997; [3] Dreher, 1994; and [4] SCCCL, 1995.

For both Duck Crossing and Stonehill Estates, the conventional design results in the highest annual volume of runoff and the lowest volume of infiltration, as was expected. Of particular interest is the fact that the controlled conventional design results in a higher annual runoff volume and a lower infiltration rate than the uncontrolled open space design. This, however, should not imply that better site design alone, without structural stormwater management, is sufficient in controlling stormwater runoff from this site since the open space designs do not come close to replicating pre-developed hydrology.

Less impervious cover and stormwater runoff, in turn, translates directly to smaller pollutant loads. Reducing the impervious cover, preserving natural areas, and providing multiple stormwater practices in series reduced nutrient export for both case studies. However, neither open space design meets pre-development nutrient loads.

One area of particular interest for Duck Crossing is the implication of on-site sewage disposal systems. The conventional design included astandard septictankand field for each lot, which resulted in phosphorus and nitrogen loads that far exceeded pre-development levels. Recirculating sand filters were used in the open space design, instead of conventional septic systems, because they yield better nitrogen removal efficiencies and are actually less expensive to construct. This resulted in a much lower nutrient output from the entire site. However, even in the open space design, the septic systems are the predominant source of nutrients.

For both case studies, the total infrastructure costs include the sum of the estimated costs of stormwater management, storm drainage, paving, sidewalk, curb and gutter, landscaping and reforestation, water, sewer and septic systems. In both cases, the open space design resulted in a cost savings. Costs associated with grading, erosion and sediment control, building construction and other incidental costs associated with land development were not analyzed. In general, these costs should be comparable between the two development options. If anything, the grading and erosion and sediment control costs should be lower with the open space design since less land is disturbed.

Several other studies have also shown that open space development can be significantly less expensive to build than conventional subdivision developments. Most of the cost savings are due to savings in road building and stormwater management conveyance costs. The use of open space design techniques at a residential development in Davis, California provided an estimated infrastructure construction costs savings of $800 per home (Liptan and Brown, 1996). Other examples demonstrate infrastructure costs savings ranging from 11 to 66%. Table 2 lists some of the projected construction cost savings generated by the use of open space redesign at several residential sites.

Table 2. Projected Construction Cost Savings for Open Space Designs from Redesign Analyses

Residential Subdivision	% Construction Savings	Notes
Duck Crossing	12%	Includes roads, stormwater management, and reforestation
Stonehill Estates	20%	Includes roads, stormwater management, and reforestation
Remlik Hall [1]	52%	Includes costs for engineering, road construction, and obtaining water and sewer permits
Tharpe Knoll [2]	56%	Includes roads and stormwater management
Chapel Run [2]	64%	Includes roads, stormwater management, and reforestation
Pleasant Hill [2]	43%	Includes roads, stormwater management, and reforestation
Buckingham Greene [2]	63%	Includes roads and stormwater management

Sources:[1] Maurer, 1996; [2] DE DNREC, 1997.

Implications for the Watershed Manager

Better site design reduces impervious cover, conserves larger contiguous natural areas, and incorporates more advanced stormwater treatment, which results in reduced stormwater runoff, increased infiltration, and reduced nutrient export. Hopefully, the results of this study, as well as other redesign analyses, will answer some of the questions of local governments, consultants, and developers as to the benefits of better site design.

However, there may still be difficulties to overcome before better site design becomes a reality and common practice in many communities. Once there is a willingness to incorporate better site design techniques into new developments, many communities may find that their existing development codes and ordinances are in conflict with the goals of better site design. For example, many local codes and ordinances require excessive impervious cover in the form of wide streets, expansive parking lots, and large-lot subdivisions. In addition, there are generally few, if any, incentives or requirements for developers to conserve natural areas. When obstacles to better site design are present, it is a sign that a community may want to reevaluate and consider changing some of its local codes and ordinances.

In 1997, CWP convened a national site planning roundtable to address this very issue. During the 18-month consensus-building process, a diverse cross section of national planning, environmental, home builder, fire and safety, and public works organizations (as well as local planning officials) crafted 22 model development principles to help further better site design at the local level. This national roundtable is serving as a model for local government implementation of better site design principles.

Recently, Frederick County, Maryland, initiated a local roundtable to take a critical look at its own development rules. Members of the development community in partnership with local planning and zoning and public works staff are meeting to identify and overcome impediments to better site design that are embedded in the county's codes and ordinances. The outcome of the consensus process should be development rules that encourage rather than discourage the application of better site design techniques.

Changing local development rules is not easy. Progress toward better site development will require more and more local governments to examine their current practices in the context of a broad range of concerns, such as how changes will affect development costs, local liability, property values, public safety, and a host of other factors. Advocates of better site design will have to answer some difficult questions from fire chiefs, lawyers, traffic engineers, developers, and many others in the community. Will a proposed change make it more difficult to park? Lengthen response times for emergency vehicles? Increase risks to the community's children? True change occurs only when the community addresses these and other questions to the satisfaction of all interests.

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